A Framework for Interaction Analysis and Feedback in Collaborative Virtual Worlds

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Abstract

Collaborative Virtual environments move more and more in the focus of CSCW research. Increasingly, empirical studies look at new and innovative uses of these platforms which were traditionally used for recreation purposes, but now also made their way into business and learning fields. These studies are all in need of data to verify their hypotheses. This paper presents a research framework which is able to collect interaction data from collaborative virtual environments. Beyond the function as a data container for analysis purposes, the framework can also directly send feedback inside the virtual environment based on the data received.

Keywords

CSCW, CVE, analysis framework, intelligent feedback

1 Introduction

Collaborative Virtual Environments (CVEs) are becoming increasingly popular and today play a role in many aspects of life, including leisure, education and work (e.g., World of Warcraft[1]: over 10 million users; Second Life[2]: 12 million accounts). Also the research area of CSCW has been looking at CVEs for professional applications for some time [Benford et al 1994]. While older studies emphasized technical realization challenges of CVEs, current research projects typically put an emphasis on human computer interaction aspects. Previous research has, for instance, looked at the different aspects of avatars like how customization options increase identification with the avatar [Vasalou, et al. 2007]. This private self-awareness allows reflecting ones attitudes, standards [Fenigstein, et. al. 1975] and emotional states [Scheier 1976]. This is helpful for some group work activities. Other studies have analyzed current CVEs to find social behavior and relationships [Ducheneaut, et al., 2006]. Most of these studies require an analysis of the behavior and the communication taking place in the CVE. This paper presents the design of a software architecture that can serve as a research framework for collecting user action/interaction data in CVEs, analyzing this data, and providing the users with feedback of various kinds. Similar work has been done before, yet with a different focus. E.g., [Chittaro, Ieronutti 2004] have developed a way to analyze avatar movement, but their tool does not consider conversation between avatars. [Biuk-Aghai, Simoff 2001] have presented a system which is centered around the question of CVE improvement in the early design stages, their system is not tailored for the use with an already existing CVE. The framework we propose in this paper is generic in the senses that a rich variety of interaction data is considered, and multiple purposes of using the data are supported. We present a concrete implementation of the framework (using the open source CVE OpenSim[3]) and three example application scenarios in the fields of Intelligent Tutoring (in emergency medical education), CSCW (development of social bonds for groups working cooperatively with a CVE), and data mining where the huge set of data might help to find new knowledge about social networking in CVEs.

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[1] Blizzard Entertainment: http://www.wow-europe.com/de/index.xml

[2] Linden Lab: http://secondlife.com/

[3] Open Simulator: http://opensimulator.org/wiki/Main_Page

2 The System Architecture

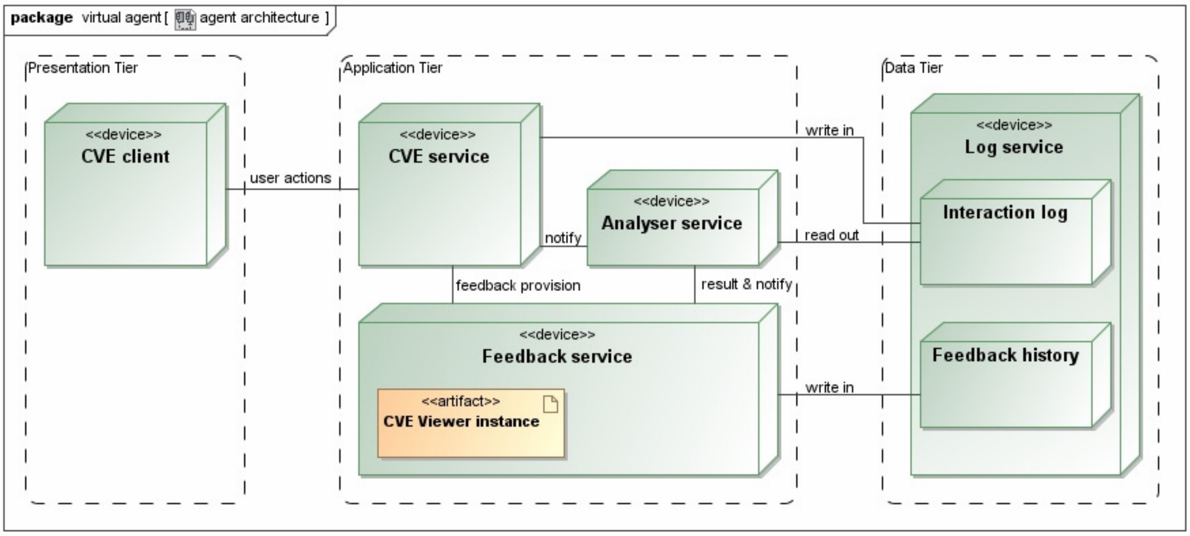

Figure 1. Software Architecture Design (Deployment View)

Figure 1 illustrates the general three-tier system architecture of the research framework we propose. At the level of the Presentation Tier, clients (i.e., CVEs used by a person) are connected to a *CVE service* which simulates a virtual world. The CVE service is connected to a logging service in the Data Tier, storing a complete log of the interaction in the CVE (cf. section 3).

The *Analyzer service* extracts data from the database in the Log service - e.g., to evaluate avatar actions. It can be informed about the existence of new data sets by the CVE service. The Analyzer service sends its results to the *Feedback service*. This is able to intervene in the CVE by executing actions on the base of the analysis results. Technically, the Feedback service can either call methods in the CVE service directly (causing the virtual world to change), or it can remote control a specific CVE client. This is an appropriate solution if the client is able to perform "macro operations" which aggregate a complex sequence of instructions to one command (which is executed by the service), or if the feedback is in the form of avatar anyway (cf. section 5). The Feedback service possesses access to an additional log function in the Data Tier to record its activities.

While the general architecture is on an abstract level and is reusable for multiple CVEs and types of analysis or feedback, the specific instantiation we have implemented uses a modified OpenSim server and a Second Life Client for the CVE components. We decided to use a relational database management system (MySQL) for the structured storage of this data (other formats would be possible here as well).

3 Data storage

The data that can be extracted from a CVE is very rich and multi-dimensional. The most important components are mainly the avatars, the artifacts (objects in the virtual world), the terrain as well as the interactions between all these. Table 1 shows a more detailed list of the information types our research framework covers and logs into the database. While some of these types are generic for all CVEs (like, e.g., avatar movement or the view angle), others are rather specific and only possible in some CVEs (such as voice chat or specific avatar appearance options).

All data sets have an ID and a timestamp. The research framework is flexible and expressive enough to log the interaction data completely (i.e., sufficient for a scene replay) and in a structured form. This is important for some of the more advanced usage scenarios (cf. section 4).

Type	Data
Avatar movement	- Avatar position on the x,y,z-axes over time - View angle
Communication	- Text chats - Voice communication (audio files) - Gestures
Appearance	- Outer appearance (body shape, clothes)
Interaction with the world	- World appearance in general (terrain, objects) - Artifacts that avatars use (modify, move, operate with)

Table 1: Interaction data.

The design of the research framework allows for an implementation of some typical and often required forms of interaction analysis and feedback in a straightforward manner. E.g., it is possible to find out which avatars are located within which area of a virtual world. If the angle of vision is included, it is possible to deduce which avatars are looking at each other. This is useful for later analysis of conversation (which avatar talked to whom?). Another option is to detect if an avatar is inactive. Furthermore, it is possible to utilize the information regarding artifacts, such as which avatars are using them. Feeding this back as awareness information can help co-workers to get a better understanding of each other's activities. Also, the framework can easily be used to implement a simple support agent – e.g., simple pre-defined commands (like "help") are detected and then cause system feedback that explains how to navigate in the CVE.

4 Usage Example

In the first sections, we described the more technical parts of the framework, such as the architecture and data storage. The subsequent paper parts illustrate some usage examples. We start by describing the functionality of the framework by means of a simple scenario. The central idea of this scenario is a virtual online store in which a bot (an automated agent) approaches the customers and provides them with advice.

Figure 2 shows a simplified illustration of the scenario. An arbitrary number of avatars can be connected to the CVE. Furthermore, an agent whose task it is to approach the avatars is included in the CVE. This agent plays the role of the sales assistant. In order to fulfill his tasks, the agent first has to search for avatars and to follow them. Additionally, the agent has to detect crowds as a collection of avatars in an area within the virtual world and has to treat them preferentially. In this case he is able to be responsive to several prospective customers at the same time. Having done this, he can then initiate further interactions with the customer avatars (not described in this paper).

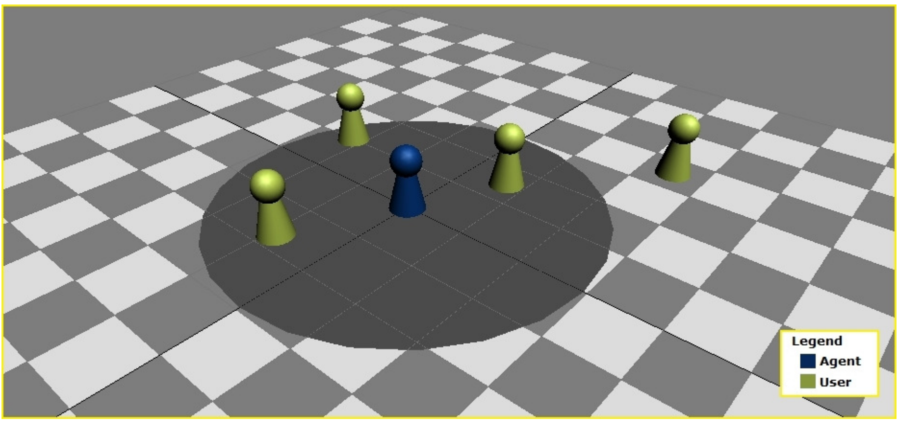

Figure 2. Conceptual 3D model: Agent in the centre of a hot spot

A modified OpenSim Server and a common Second Life Viewer provide the basis for the scenario. The OpenSim Server administrates the 3D CVE and stores every movement of the clients in the database. In our application, the Analyzer Server periodically (every 5 seconds) queries the database and evaluates the retrieved data on the basis of the following criteria:

- First it is checked if a group of avatars stays within a certain area of the virtual world. For this, it is necessary to compare the positions of the avatars. If more than two avatars are located within a radius of 10 meters, the agent identifies this area as a hot spot and moves towards its centre. (In comparison: the total size of the virtual world amounts to approx. 65.536 m²).
- In the event that a hot spot is found, the bot stays there until the hot spot breaks up (less than three avatars).
- If it is not possible to find such a hot spot, the agent looks for the closest avatar and moves towards it or follows it.

In doing so, the Analyzer Server regards the (x,y,z) coordinates of the avatars within the virtual world. This is shown in the following excerpt from a log file of this scenario. In the excerpt, the OpenSim Server registers the changes of the positions of avatars 1 and 3 and stores them in the database. During the periodical query of the data by the Analyzer Server a hot spot is detected. This service instructs the Feedback Server to route the agent towards the centre of the hot spot.

Service	**action**	**timestamp**
OpenSim	send to DB: avatar 1 moved from (139.806;129.566;21.450) to (145.022;129.566;21.450)	03/18/08 10:23:52
OpenSim	send to DB: avatar 2 moved from (139.806;129.566;21.450) to (145.022;129.566;21.450)	03/18/08 10:24:07
Analyzer	retrieve data from DB	03/18/08 10:24:08
Analyzer	found hotspot at (148.266;126.323;21.450)	03/18/08 10:24:08
Analyzer	send task to agent: move agent to (148.266;126.323;21.450)	03/18/08 10:24:08
Feedback	Agent moved from (57.457;101.363;21.450) to (148.266;126.323;21.450)	03/18/08 10:24:19

Table 2: Excerpt from Log Service

Figure 3 shows a screen taken from the implemented scenario. The screen was shot from an avatars point of view while located inside of a hot spot that the agent was moving towards.

Figure 3. Agent moves to the centre of a hot spot

In this online store example, the next step could be to evaluate conversations regarding products between avatars. Based on the analysis of these conversations, the agent could recommend products and services to these avatars.

5 Advanced Applications of the Framework

Also beyond the simple uses described above, the system architecture constitutes a framework which can be used as an enabling technology for the investigation of a variety of research questions in several fields related to virtual 3D spaces. These include data mining, intelligent tutoring, and CSCW. In the following, we briefly outline ongoing projects in these fields in which the research framework is applied.

5.1 Collaboration Mining

In 3D-CVEs, massive log data can be gathered, resulting in several GB of raw data on a daily basis - calculated based on the usage statistics of Second Life (500 000 users, active for 30 hours per month, assuming one user action per second, with an average of 20 bytes per log entry). Thus, within a month, the accumulation of a TB of log data is a realistic assumption. This multi-media, multi-dimensional log data, collected in the framework, provides challenging and rich material that is an interesting test case for novel *collaboration data mining* techniques which can, e.g., serve the purposes of determining relevant aspects of the multidimensional avatar connections, and extracting social binding information from the log data. These techniques can help solving the crucial problem of finding out which users interacted with which via avatars (e.g., through repeated conversations, frequent gaze contact, co-location joint operation on artifacts). This is much harder to determine than in 2D systems such as blogs or discussion forums, where interaction information is much more explicit and easier to analyze (e.g., links, replies to forum posts). In the 3D case, the following steps are appropriate to determine relevant interactions based on log data and machine learning techniques:

- identify atomic episodes (training data) in the raw log data
- extract information from training data towards meaningful semantic groups
- build enriched social network graphs from this information and the automatic determination of network aspects which are judged as relevant

The architecture presented in this paper easily allows the inclusion of such data mining components using various algorithmic techniques [Rauber, et al. 2002; Alex, et al. 2007] in the Analysis Service. As described, these components can be used to extract social binding information, visualize them to users and offer them to users as a tool for interaction, navigation and decision support – e.g., to recommend potential interaction partners to users based on preferences and interaction behavior in the 3D-CVE.

5.2 Intelligent Tutoring

In the educational technology domain, a number of recent research projects used virtual worlds as a rich interaction device for students [e.g., Chitarro, Ronan 2007]. The architecture proposed in this paper easily allows for the inclusion of *intelligent tutoring* components – e.g., through the inclusion of intelligent feedback agents that have an avatar representation in the virtual world [Livingston, Kemp 2006]. Concerning the method of delivering feedback to users, the easiest way of communication is to send a text message via the CVE service. This is available in many CVEs such as Second Life or OpenSim. A more advanced alternative solution is to use independent avatars controlled by the Feedback Service. This form of feedback provision has certain advantages [Schrammel, et. al. 2007; Xiao, et. al. 2007]. E.g., if the avatar agent mirrors user gestures, he can create a stronger social bond [Bailenson, Yee 2005].

We currently design and test an example ITS, using the framework in emergency field where medical staff needs to learn identifying injuries quickly (cf. Figure 4). The traditional training of

Emergency Medical Technicians (EMT) is a combination of two-dimensional information like books and pictures and practical exercises where real people act as if they are injured. 3D environments can create visual situations which are more realistic than in 2-dimensional books or difficult to reproduce with healthy actors. One example are broken bones, they cannot be easily be simulated by an actor. There is some evidence that ITSs with CVEs can be helpful in the medical field [Chieu, et al. 2007]

Our study hypothesis is that 3D training is more efficient than book studies. The framework is used to analyze the training behavior of students. In particular, the framework can analyze the time needed to find the important clues (e.g. low blood pressure, high pulse, bleeding) and the correct diagnostic (shock based on blood loss). This is possible since the framework saves the conversations and interaction of the team (EMT training is usually done in teams, so our ITS does so as well). Once the initial study confirms the general suitability of our approach to CVE training in the EMT field, the system can be extended with a feedback option. An avatar can represent a teacher capable of answering basic medical pre-programmed questions. If certain key diagnostics of measures have not been taken by the EMTs, the program will give help (like: "Maybe you should check the pulse").

Figure 4: Two paramedics are questioning a casualty about what happened

5.3 Support of CSCW

Through their interaction forms and personality representation, 3D collaborative virtual environments are suitable tools for supporting group work in many domains. The framework can serve as a tool to analyze, better understand and support the group processes. E.g., this can be achieved through awareness techniques using the Analysis Service to check the state of a collaboration process and mirror it back to the users.

An ongoing study investigates the cooperation options in virtual environments as compared to regular meetings for the task of collaborative story writing. The focus of the study will be to see differences in the development of social bonds comparing cooperating real life and CVE groups. Studies have shown that social bonds among co-workers are important for companies to improve productivity [Kramer 1999]. Different electronic media have shown to result in different speeds and efficiencies when it comes to building social bonds [Bos, et. al. 2002]. A human-like representation of users in form of an avatar can lead to social bonds with the co-worker that, as wee hypothesize, might be stronger than those resulting from email or chat communication.

For our study, collaborative story writing was chosen as the domain in which the users will have to cooperate and communicate. Several stories will have to be written by the group. These will all be linked, as they are supposed to represent different points of view on the same event. Writing such linked and interdependent stories will require the users to collaborate. In the CVE condition, the stories will be represented as separate objects. This way, avatars can only work on one story, while seeing on which story the other co-workers work on. A control condition will be allowed to meet in real life to coordinate their efforts. The study is supposed to show differences in productivity between these two groups. We will also analyze the development of social bonds in these two conditions. The productivity can easily be seen at the quality and the amount of the writing results, the number of interactions between the texts and the mistakes made (e.g., inconsistencies between the stories). The research framework presented in this paper will be used to analyze the communication behavior of users. The amount of chat will be analyzed as well as changes in talking behavior or the increase or decrease of private communication versus work communication. These changes in communication behavior can be indicators for changes in the social structure of the group while they collaborate with each other.

6 Conclusion

3D collaborative virtual environments are clearly still on the rise. They are being increasingly used in cooperative work, leisure and learning scenarios, and it is realistic to assume that with increasing network bandwidth and computing power, today's usage frequencies of these systems are still much lower than they will be in some years from now. Largely due to the rich interaction forms they support, user interactions in 3D CVEs are considerably more complex than in traditional 2D environments. In order to understand user actions and interactions in 3D CVEs (e.g., to provide them with adaptive support), tools to analyze user behavior are required.

This paper proposed a software architecture that allows the flexible collection of user interaction data in 3D collaboration environments. The architecture consists of three tiers and allows the logging of user actions and interactions in CVEs, the analysis of these actions, and the provision of feedback. Through its modular design, the architecture is suitable for different CVEs. Also, the interaction analysis and feedback components can be added easily.

Implementations of this architecture can act as a research framework, enabling the investigation of social interactions in metaverses. We have given examples from three different application areas for which this framework can be helpful. These include Collaboration Mining (determining social networks in CVEs based on log data), Intelligent Tutoring (providing feedback for training in the emergency medical field), and Computer Supported Cooperative Work (detailed interaction logs are the base data for some study hypotheses). Our research in these fields is ongoing: while the system architecture is completed and running, the empirical studies described in the paper have not been completed yet. In the future, we expect to extend and modify the framework (in particular, the analysis and feedback services) based on the results of these studies.

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